2. Program Benefits

"Hydrogen can be produced from domestic sources—initially, natural gas; eventually, biomass, ethanol, clean coal, or nuclear energy. One of the greatest results of using hydrogen power, of course, will be energy independence for this nation. … If we develop hydrogen power to its full potential, we can reduce our demand for oil by over 11 million barrels per day by the year 2040. That would be a fantastic legacy to leave for future generations of Americans."

President George W. Bush
The National Building Museum
February 6, 2003

"Now, there's a lot of obstacles that must be overcome in order to make fuel cells economically viable. And, therefore, we're promoting more research and development. In January, Secretary Abraham announced a $150 million FreedomCAR plan."

President George W. Bush
The South Lawn
February 25, 2003

The President's FreedomCAR and Hydrogen Fuel Initiative is designed to reverse the United States' growing dependence on foreign oil by developing the technologies that lead to hydrogen-powered hybrid fuel cell vehicles. This initiative was chosen primarily because of the energy security benefits associated with a transportation fuel that can be produced domestically from a diversity of feedstocks. Of the $150 million in funding for this initiative announced by Energy Secretary Abraham, approximately half is for fuel cell and hydrogen research; the other half is for nearer-term automotive technologies within the FreedomCAR and Vehicle Technologies (FCVT) Program that improve energy efficiency and provide the transition to hybrid fuel cell vehicles using hydrogen. The R&D conducted by FCVT serves the objectives of the Initiative in three ways:

1. Reducing petroleum dependence in the near term by improving hybrid vehicle technology [with gasoline or diesel internal combustion engines (ICEs)] and clean fuels while fuel cell technology is still being developed.
2. Developing additional technologies, such as power electronics, energy storage, and lightweight materials, that will eventually be needed for fuel cell vehicles.
3. Stimulating the development of a hydrogen infrastructure through the near-term use of transitional liquid fuels and hydrogen in ICEs.

The *Multi-Year Research, Development and Demonstration Plan* for EERE's Hydrogen, Fuel Cells, and Infrastructure Technologies (HFCIT) Program presents the rationale and potential national benefits for pursuing technologies that provide an increase in energy security through reduced petroleum dependence and a reduction in both criteria pollutants and greenhouse gas emissions in transportation. The factors that provide the rationale for a government role in R&D in vehicle energy use can be summarized as follows.

U.S. crude oil production can provide for some of the nation's petroleum needs; however,

- Crude oil production peaked in 1970.
  - — It has declined steadily since the mid-1980s, even with the addition of oil from Alaska's North Slope.
- Oil imports are a growing national concern.
  - — The United States imports more than half its oil (compared with a third during the 1973 oil crisis).
  - — Oil imports are expected to exceed 70% by 2025.
- Three trillion barrels of recoverable oil exist worldwide—a finite resource (U.S. Geological Survey).
  - — One fourth of the oil has already been produced and consumed.
  - — One-fourth of the oil has been discovered and "booked as reserves."
  - — One-half is either reserve growth or probable, but undiscovered, resources.
  - — Oil is relatively abundant, but it
    - ▪ is distant from most major consumers,
    - ▪ has an uneven geographic distribution, and
    - ▪ is concentrated in regions that have either political or environmental sensitivities.
- Global transportation trends in petroleum consumption will increase oil demand.
  - — Transportation oil use continues to grow in industrialized countries.
  - — Growth in transportation oil consumption in developing countries will accelerate as their economies modernize. For example, in terms of vehicles per person, China is where the United States was in 1913; but it is growing at twice the current U.S. rate.

In addition, carbon emissions, which are directly proportional to the carbon in the fuel, result in greenhouse gases, such as carbon dioxide and methane, that are considered to have a detrimental effect on the global climate. The conclusion from the energy and environmental trends is that the world cannot remain forever dependent on petroleum fuels; therefore, a transition will be necessary at some point. The earlier the transition is begun, the smoother the process is likely to be (i.e., there will be fewer economic shocks due to fuel price spikes). The FreedomCAR and Hydrogen Fuel Initiative provides for such a transition. Hydrogen and hybrid fuel cell vehicles provide the eventual shift to a new transportation fuel using new powertrains for the vehicles. The FCVT Program provides a number of enabling technologies for that transition, as well as near-term relief from excessive dependence on imported petroleum.

Energy Security Benefits

The Presidential FreedomCAR and Hydrogen Fuel Initiative identifies the potential for reducing the nation's demand for oil by over 11 million barrels per day by the year 2040. This reduction in petroleum demand is due to the displacement in fuel consumption provided by hydrogen vehicles and hybrid fuel cell vehicles. Hybrid fuel cell vehicle research is anticipated to be completed by 2015. Meeting both the performance and economic goals would allow business decisions to be made and provide the basis for significant market penetration beginning three years later.

Hybrid fuel cell vehicles will benefit significantly from reducing the weight of the vehicle and from the widespread adoption of hybrid electric vehicle (HEV) propulsion systems, including improved energy storage systems that allow start-up with a battery or other energy storage device and the ability to capture energy via regenerative braking. These technologies will have petroleum savings benefits of their own well before the introduction of hybrid fuel cell vehicles. The petroleum reduction benefits of hybrids are smaller than those of fuel cells because hybrid fuel cell vehicles are projected to be more efficient and in this analysis are assumed to use non-petroleum feedstocks for hydrogen. Nevertheless, oil savings from HEVs (gasoline or diesels) in the near term can be significant and can occur sooner than savings from hybrid fuel cell vehicles.

The oil savings benefit of successful market penetration of technologies supported by DOE in the FreedomCAR and Fuel Partnership and the 21st Century Truck Partnership (21st CTP) has been simulated as a part of the required Government Performance Results Act (GPRA). For light-duty vehicles, two separate analyses were conducted because the FreedomCAR and Fuel Partnership is engaged in R&D of mid-term technologies (e.g., hybridization, high-power-density batteries, lightweight materials, improved combustion, alternative fuels) as well as longer-term technologies (hydrogen and fuel cells). The development of the nearer-term technologies is the focus of the FCVT Program, while hydrogen and fuel cell development is the responsibility of the HFCIT Program. FCVT is also the major federal R&D organization for heavy truck technology development in the 21st CTP.

The GPRA simulations were developed using two models: (1) the National Energy Modeling System (NEMS) developed by the Energy Information Administration for forecasts to 2025, and (2) for 50-year forecasts, the MARKAL model, developed in a cooperative multinational project over a period of almost two decades by the Energy Technology Systems Analysis Programme of the International Energy Agency.

Oil Savings in Light-Duty Vehicles

In a "stand-alone" simulation, the FCVT-supported technologies are commercialized (alone, without any hybrid fuel cell vehicles) by the FreedomCAR and Fuel industrial partners. Initial commercialization begins by 2010 with modest market penetration in light-duty vehicles as well as heavy trucks. Because the FCVT-supported technologies (components, subsystems, and systems) are commercialized in new vehicles, it takes time for the more efficient vehicles to become a substantial share of the stock of on-the-road vehicles and for the oil savings benefits to accumulate. The technologies that become commercial include accelerated growth in HEVs with advanced batteries, increased use of lightweight materials, and advanced combustion processes. The petroleum reduction is relatively modest until 2025, but then the oil savings grow at a rapid rate. Oil savings nearly double between 2025 and 2030, from 1.1 million barrels per day (MMBD) to 2.0 MMBD. By 2040, petroleum savings are forecast to be nearly five MMBD, continuing to almost seven MMBD by 2050.

A second case that was analyzed is called Integrated Vehicle Technologies, which includes FCVT technologies and hybrid fuel cell vehicles. Many of the FCVT technologies not only provide oil savings benefits on their own but also facilitate fuel economy improvements in hybrid fuel cell vehicles. For example, hybridization and advanced batteries enable hybrid fuel cell vehicles to take advantage of regenerative braking. Lightweight materials enable any vehicle, regardless of its propulsion system, to be more energy-efficient.

Hybrid fuel cell vehicles, because of complexities and hydrogen fueling infrastructure issues, are commercialized later than the FCVT technologies, beginning in about 2020. So the oil savings benefits for the decade between 2010 and 2020 are due to FCVT-supported technologies. Hybrid vehicles with conventional engines are still predominant until 2025, after which both conventional hybrids and hybrid fuel cells share the light-duty vehicle market. This sharing of the market continues for the foreseeable future; although hybrid fuel cells are more energy-efficient, conventional hybrids remain less expensive. In the Integrated Vehicle Technology case, the FCVT light-duty vehicle portion of the oil savings continues to grow, from 0.5 MMBD in 2020 to 1.6 MMBD in 2030 to 3.1 MMBD in 2040. Oil savings still increase after that, but at a slower rate.

Oil Savings in Heavy-Duty Vehicles

Heavy trucks account for about one-fourth of the energy consumed by highway vehicles. Much of the nation's high-value freight is shipped by trucks, and the propulsion system for over-the-road trucks (Class 8) is dominated by relatively efficient diesel engines. Nevertheless, there is room for energy efficiency improvements. The FCVT Program also supports technology development to improve medium- and heavy-duty truck fuel economy. This research is focused on advanced combustion, improved aerodynamics and rolling resistance, heavy hybrid technology (focused on class 3–6 trucks), and essential power systems. The oil savings potential of fuel economy improvements in heavy-duty vehicles was also evaluated with the NEMS and MARKAL models.

The petroleum savings benefits for heavy-duty trucks remain the same in both the stand-alone and Integrated Vehicle Technology cases. Modest fuel savings begin in 2010 with the introduction of the initial technologies. Oil savings in both cases grow to nearly one million barrels per day by 2035, and continued savings are a little above this level for the out-years, as shown in Figures 9 and 10.

Greenhouse Gas Emissions

Upstream emissions (well to pump or WTP) that occur in the production and distribution of fuels may be as important as vehicle emissions (pump to wheel or PTW). Gasoline and diesel HEVs can have considerable greenhouse gas (GHG) benefits, as illustrated in Figure 11. Based on examining the total energy cycle on a per-vehicle basis using the GREET (Greenhouse gas, Regulated Emissions, and Energy use in Transportation) model, hybridization can reduce GHG emissions by nearly 50% compared with conventional vehicles, providing additional environmental benefits of a transition to the goal of hybrid fuel cell vehicles operating on hydrogen.[1] The fuel economy improvements achieved by heavy-duty vehicles will also contribute to a reduction in GHG emissions, as carbon emissions from petroleum are directly related to fuel economy. The MARKAL simulation of the technologies developed with the support of FCVT forecasts carbon emissions reductions of over 300 million metric tons (carbon equivalent) by the year 2050.

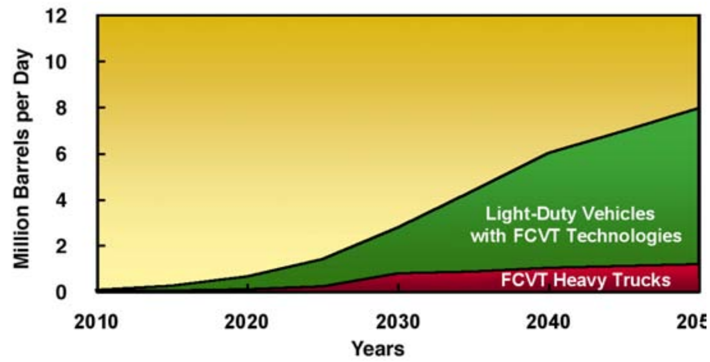

Figure 9. Oil savings due to FCVT if hybrid fuel cell vehicles are not introduced.

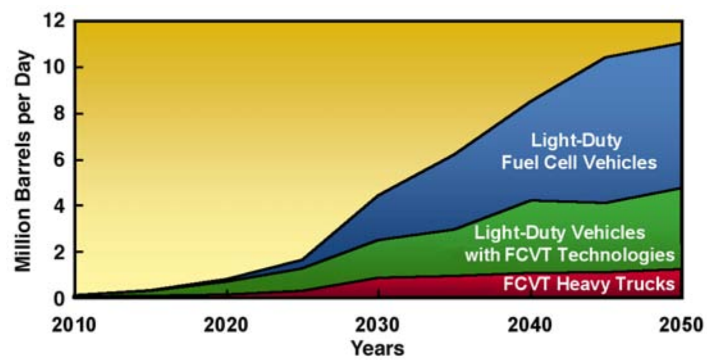

Figure 10. Integrated fuel savings of FCVT and HFCIT

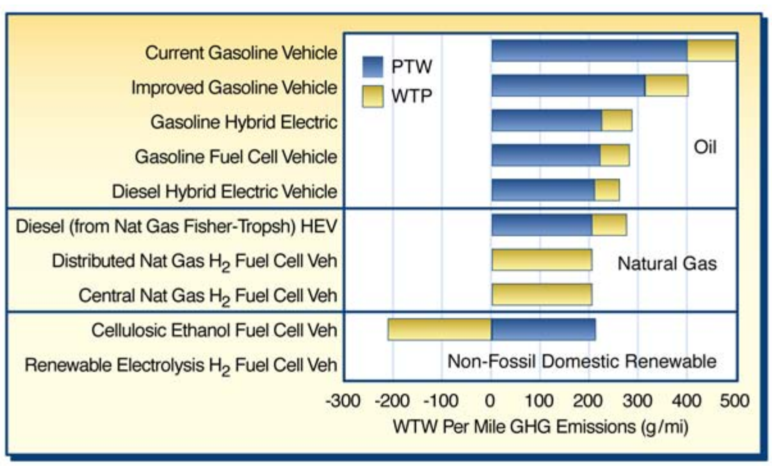

Figure 11. Comparative total energy cycle greenhouse gas emissions from selected vehicle technologies.

[1] M. Q. Wang, *Development and Use of GREET 1.6 Fuel-Cycle Model for Transportation Fuels and Vehicle Technologies*, ANL/ESD/TM-163, Argonne National Laboratory, June 2001.